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Influence of Wildfire on Selected Streams in the Payette National Forest

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

Habitat characteristics and benthic communities were investigated, in relation to wildfire, in several streams within the Payette National Forest. Drainage basin aspect influenced stream habitat conditions, but the interactions between wildfire and basin aspect are not yet clearly understood. The removal of riparian vegetation (i.e., shading) by wildfire was suggested to create a warmer and more variable thermal regime in streams. Periphyton abundance was greatest in streams with an open canopy, suggesting the potential for wildfire to increase periphyton abundance through removal of riparian shading. Distinct differences were observed in the macroinvertebrate community of the burned and unburned reach of Cliff Creek, with the burned reach dominated by sediment-dwelling taxa. In general, the hypothesis that stream recovery from wildfire would be concurrent with terrestrial recovery was supported.

INTRODUCTION

Wildfire is the predominant natural, large-scale disturbance experienced by streams of the Intermountain West. Nonetheless, knowledge regarding the effects of wildfire on stream ecosystems remains limited; although the body of literature is growing (e.g., Albin 1979, Minshall et al. 1995, Richards and Minshall 1992, Robinson et al. 1994, Spencer and Hauer 1991). Minshall et al. (1989a) hypothesized that return of stream benthic habitats and communities to a pre-fire condition would occur concurrently with recovery of the surrounding terrestrial landscape.

The primary research goal during 1994 was to examine the recovery of streams that had experienced wildfire at various times in the past and to compare conditions in those streams with unburned reference streams. Furthermore, the results provided base-line habitat and macroinvertebrate data against which the effects of future disturbances (natural or anthropogenic) could be measured. The present study continued monitoring the long-term study streams in the Big Creek catchment within the Frank Church "River of No Return" Wilderness Area, and initiated sampling in four tributaries of the South Fork of the Salmon River.

STUDY SITE DESCRIPTIONS

The study streams were located within the Payette National Forest in central Idaho either (1) along Big Creek in the Frank Church "River of No Return" Wilderness Area or (2) along the South Fork of the Salmon River (Table 1). Study streams in the Big Creek catchment were influenced, to varying degrees, by either the Golden Fire of 1988 or the Rush Point Fire of 1991. The catchments of Cliff, Cougar, Goat, and Dunce Creeks were affected by the Golden Fire; Cave and Cabin Creeks acted as a reference for these sites. All of the above streams had a

Table 1. Location of the study streams in the Big Creek and S.F. Salmon catchments.

Stream	Elevation (m)	Longitude	Latitude	Township	Range
Big Creek Catchment					
Rush Cr.	1170	114 51'W	45 07'N	T20N	R13E
Pioneer Cr.	1170	114 51'W	45 06'N	T20N	R13E
Cave Cr.	1220	114 57'W	45 08'N	T21N	R12E
Cabin Cr.	1300	114 56'W	45 09'N	T21N	R12E
Cliff Cr. (upper)	1680	114 51'W	45 08'N	T20N	R13E
Cliff Cr. (lower)	1200	114 51'W	45 07'N	T20N	R13E
Goat Cr.	1130	114 48'W	45 07'N	T20N	R13E
Cougar Cr.	1100	114 49'W	45 07'N	T20N	R13E
Dunce Cr.	1160	114 47'W	45 07'N	T20N	R14E
S.F. Salmon Catchment					
Circle End Cr.	1110	115 39'W	45 20'N	T20N	R06E
Tailholt Cr.	1110	115 39'W	45 15'N	T20N	R06E
Pidgeon Cr.	1110	115 38'W	45 15'N	T20N	R07E
Fitsum Cr.	1150	115 49'W	45 00'N	T19N	R06E

southern aspect. Rush and Pioneer Creeks were minimally influenced by the Rush Point Fire and had northern aspects, thus they provided a comparison with the south-facing streams listed above. Study streams in the South Fork of the Salmon River catchment were influenced by the Fitsum Fire of 1919 (Fitsum Cr.) or the Circle End Fire of 1949 (Tailholt, Circle End, and Pidgeon Creeks).

METHODS

General field methods used for the various segments of this study are summarized in Table 2. The methods were consistent with methods used in our previous studies of wildfire and wilderness streams. These are relatively routine in stream ecology and are described in detail in standard reference sources (Weber 1973, Greeson et al. 1977, Lind 1979, Merritt and Cummins 1984, APHA 1992) or in more specific references listed in Table 2. Mean substratum size, water depths, and near-bed water velocities were determined at 100 random locations along a substantial (ca. 200 meter) reach of stream. Methods for sampling macroinvertebrates are described in Platts et al. (1983). Procedures for sample analysis also are described in Table 2. Macroinvertebrates were examined in terms of density, biomass, species richness, and Simpson's Index.

Diatom samples were collected using methods described in Robinson and Rushforth (1987). The method involved scraping periphyton from 3-5 rock substrata in each stream, compositing the individual samples, and preserving them with 5% formalin. In the laboratory, the composite samples were boiled in concentrated nitric acid, rinsed, mounted in Naphrax mountant, and examined under 1000 x oil immersion using a Zeis RA microscope with Nomarski optics (St. Clair and Rushforth 1976). For each sample, approximately 1000 diatom valves were enumerated and identified to species.

Table 2. Summary of variables, sampling methods, and analytical procedures used in the study.

Variable	Type*	Sampling Method	Analytical Method	Reference
A. Physical				
Temperature	P	Continuous measurement with a datalogger	Calculate temp. indices	
Substratum Size	R	Measure x-axis of 100 randomly selected substrata	Calculate mean substratum size	Leopold 1970
Substratum Embed-dedness	R	Visual estimation on 100 randomly selected substrata	Calculate mean substratum embededdness	Platts et al. 1983
Stream Width	T	Measure bank-full width using a nylon meter tape	Calculate mean stream width	Buchanan and Somers 1969
Stream Depth	R	Measure water depth at the 100 randomly choosen substrata	Calculate mean water depth	
Discharge	T	Velocity/depth profile Velocity measured with a small C-1 Ott meter	Q=WxDxV; where Q=discharge, W=width, D=depth, and V=vel	Bovee and Milhous 1978
B. Chemical				
Conductivity	P	Field measurement	Temperature comp-ensated meter (Orion model 126)	APHA 1992

* P=point measure; T=transect across stream; R=random throughout a defined reach.

Table 2 (cont.).

Variable	Type*	Sampling Method	Analytical Method	Reference
pH	P	Field measurement	Digital meter (Schott model CG837)	APHA 1992
Alkalinity	P	Single water sample	Methly-purple titration	APHA 1992
Hardness	P	Single water sample	EDTA titration	APHA 1992
C. Biological				
Invertebrates	R	Collect 5 samples using a Surber sampler	Remove invertebrates, identify, enumerate, and analyze community properties	Platts et al. 1983, Merritt and Cummins 1984
Periphyton	R	Collect samples from 5 individual substrata	Methanol extraction	Robinson and Minshall 1986
Diatoms	R	Collect samples from 5 individual substrata	Identify to species	St. Clair and Rushforth 1976, Robinson et al. 1994
Benthic Organic Matter	R	Recover from Surber samples	Determine AFDM	

* P=point measure; T=transect across stream; R=random throughout a defined reach.

RESULTS

Big Creek Long-term Monitoring Sites

In general, the study streams showed little temporal variation in terms of physical and chemical parameters (Table 3). Goat, Cougar, and Dunce Creeks consistently displayed greater channel slope than have the other streams, possibly a result of down-cutting following wildfire. Within each stream, benthic habitat heterogeneity measures displayed little temporal variation (Table 4).

Thermal conditions were distinctly different between Cliff, Pioneer, and Rush Creeks (Fig 1.). During the summer months mean daily water temperatures were consistently warmer in Rush Creek than either Cliff or Pioneer. This was likely due to the larger size and open canopy of Rush Creek, as opposed to the closed canopy above Cliff and Pioneer. Directional aspect of the basin also influenced stream temperatures. For example, Cliff Creek (southern aspect) was warmer and accumulated more degree days than did Pioneer Creek (northern aspect). Daily temperature range (daily maximum - daily minimum) was consistently greater in Rush Creek than either Cliff or Pioneer, which suggested greater thermal constancy in Cliff and Pioneer. In general, a closed canopy above a stream resulted in cooler, but more constant, thermal conditions within the stream.

Benthic organic matter (BOM) measured during 1994 was similar to that observed in previous years for Rush, Pioneer, Cave, Cliff, and Cougar Creeks (Fig. 2). Goat Creek displayed a BOM value similar to that of 1993, but reduced from 1990-1992. The BOM value measured in Dunce Creek in 1994 was approximately 50% of that recorded in 1992. Periphyton chl *a* values obtained in 1994 were notably reduced from 1993 values in Rush, Cave, and Cliff Creeks (Fig. 3). Pioneer, Goat, Cougar, and Dunce Creeks have exhibited relatively constant chl *a* levels over time.

Table 3. Physical and Chemical measures for study streams in the Big Creek catchment.

Stream	Year	Discharge (m3/s)	Slope (%)	Alkalinity (mg CaCO3/L)	Hardness (mg CaCO3/L)	Specific Conductance (uS/cm @ 20C)	pH
Rush	1988	1.61	1	36	30	110	7.8
	1991		1			103	8.2
	1992	1.10	1	46	46	95	8.4
	1993	0.31	3				7.9
	1994	1.56				77	
Pioneer	1990	0.16	3	62	86	88	8.1
	1991	0.01	3			125	8.0
	1993	0.02	6	26	48	72	
	1994	0.17				113	
Cave	1990	0.31	6	24	44	39	7.9
	1993	0.08	3	19	24	55	
	1994	0.21					
Cliff	1990	0.32	10	35	66	61	8.2
	1991	0.18	11	77	71	73	8.2
	1992	0.08	9	48	49	99	8.0
	1993	0.09	6	26	44	77	7.7
	1994	0.10				79	
Goat	1990	0.01	18	86	110	139	8.1
	1991	0.09	18	49	51	153	8.4
	1992	0.01	18	80	76	151	8.2
	1993	0.01	17	41	68	116	8.1
	1994	0.01				148	
Cougar	1990	0.11	12	46	71	70	8.5
	1991	0.10	12	36	32	93	7.4
	1992	0.01	13	59	60	113	8.2
	1993	0.02		33	48	94	7.7
	1994	0.08					
Dunce	1990	0.02	15	76	100	129	8.3
	1991	0.15	15	82	78	168	8.5
	1992	0.01	15	74	67	142	8.2
	1994	0.01				150	

Table 4. Habitat heterogeneity measures for study streams in the Big Creek catchment.

Stream	Year	Near-bed Velocity (cm/s) mean (n=100)	Near-bed Velocity SD	Substrate Size (cm) mean (n=100)	Substrate Size SD	Substrate Size CV	Substrate Embeddedness (%) mean (n=100)	Substrate Embeddedness SD	Substrate Embeddedness CV	Bankfull Width (m) mean (n=5)	Bankfull Width SD	Baseflow Depth (cm) mean (n=100)	Baseflow Depth SD	W:D Ratio
Rush	1988	49.0	21.0	14.6	14.0	0.96				15.1		35.0	10.0	43.1
	1992	11.0	6.5	13.3	9.2	0.69	18.8	26.7	0.96	12.0		21.0	10.0	57.1
	1993	14.7	7.1	21.3	14.8	0.69	35.0	28.9	0.51	13.4	1.5	26.2	7.3	51.1
	1994			13.9	13.2	0.95	39.3	34.0	0.46	6.3	4.8	26.2	7.9	24.0
Pioneer	1990	33.0	27.0	16.7	14.0	0.84	12.5	23.9	1.44	3.4		16.0	4.5	21.3
	1993	17.2	11.9	19.5	18.7	0.96	33.8	28.8	0.53	2.9	0.9	15.3	7.7	19.0
	1994			13.9	15.2	1.09	34.3	33.7	0.53	1.7	4.2	18.0	7.9	9.5
Cave	1990			18.8	12.2	0.65				6.1		15.0	6.0	40.7
	1993	14.1	10.9	18.2	17.0	0.93	59.8	29.8	0.30	5.4	0.5	15.3	8.1	35.2
	1994			18.3	15.9	0.87	45.0	33.9	0.40	4.1	8.1	15.6	9.5	26.2
Cliff	1990			25.3	17.7	0.70				3.5		20.0	4.0	17.5
	1991			22.5	20.3	0.90				3.8		20.0	8.0	19.0
	1992			26.8	26.8	1.00				5.5		20.0	14.0	27.5
	1993	13.4	11.2	21.5	16.8	0.78	41.8	31.6	0.43	3.2	0.7	16.4	8.3	19.5
	1994			19.5	16.3	0.84	40.9	30.8	0.44	2.0	6.4	20.9	10.2	9.6
Goat	1990			9.7	16.5	1.70				0.9		10.0	2.0	9.0
	1991			10.9	16.4	1.50				0.9		10.0	3.0	9.0
	1992			13.1	17.0	1.30				0.8		10.0	7.0	8.0
	1993	14.9	8.5	17.5	16.6	0.95	43.8	35.4	0.41	1.1	0.3	12.0	4.1	9.2
	1994			11.7	16.1	1.38	68.5	31.1	0.26	0.9	0.2	10.4	4.4	8.8
Cougar	1990			21.6	13.0	0.60				2.7		20.0		13.5
	1991			22.6	27.1	1.20				3.1		20.0	6.0	15.5
	1992			13.0	14.3	1.10				2.6		20.0	20.0	13.0
	1993	11.9	12.4	21.1	20.9	0.99	42.5	30.5	0.42	2.5	0.9	16.3	8.1	15.3
	1994			15.5	11.9	0.77	50.3	33.8	0.36	1.6	0.7	18.8	10.3	8.5
Dunce	1990			21.3	32.0	1.50				1.1		10.0	3.0	11.0
	1991			13.9	22.2	1.60				1.1		10.0	2.0	11.0
	1992			4.7	14.1	3.00				1.2		10.0	7.0	12.0
	1994			13.8	22.0	1.59	70.8	31.6	0.25	0.9	0.3	10.0	4.9	9.0

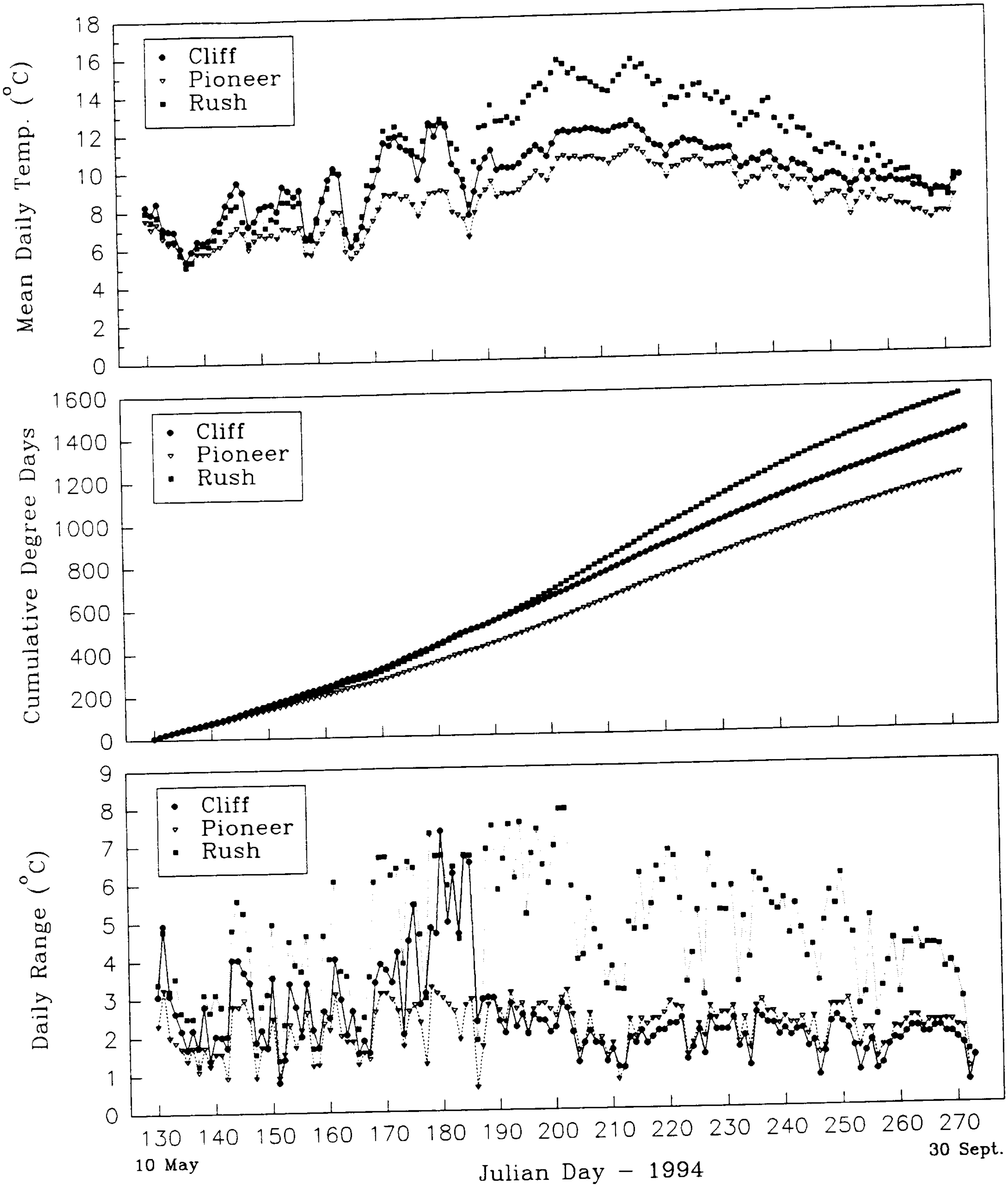

Fig. 1. Mean daily temperature, cumulative degree days, and daily temperature range for Cliff, Pioneer, and Rush Creeks. Results calculated from readings taken every 1.6 hours.

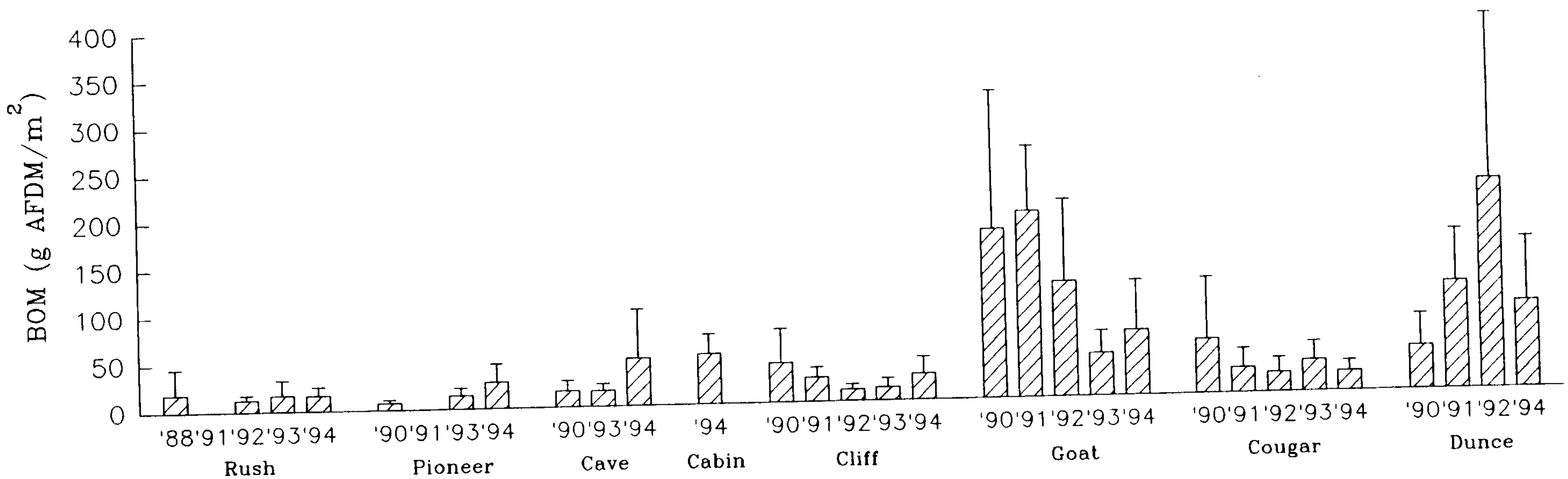

Fig. 2. Benthic organic matter (BOM) values for the study streams. Error bars equal one SD from the mean, n=5.

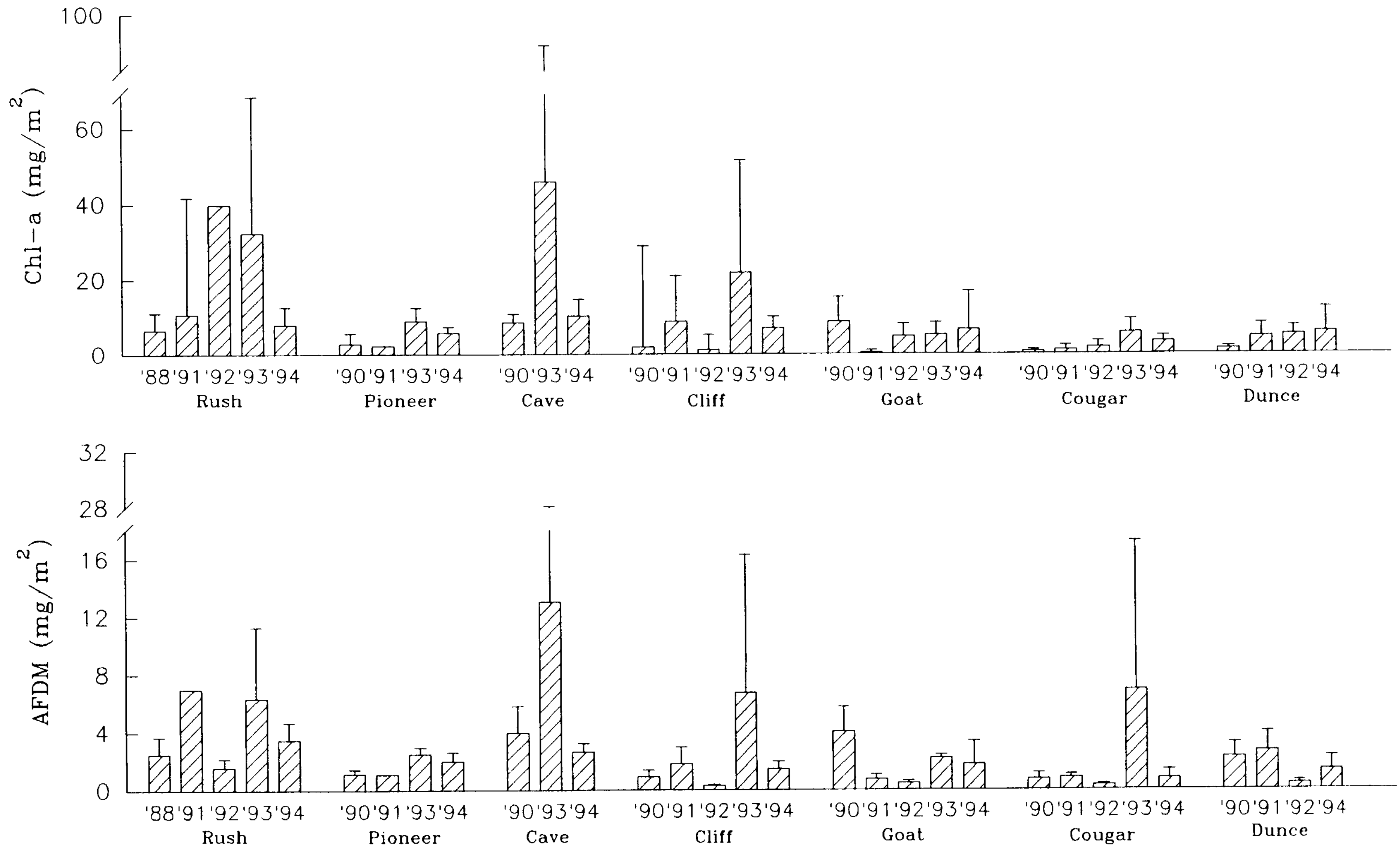

Fig. 3. Periphyton chlorophyll-a and ash-free dry mass (AFDM) values for the study streams. Error bars equal one SD from the mean, n=5.

Periphyton ash-free dry mass (AFDM; a measure of the organic content of the periphyton matrix) displayed patterns similar to those for chl *a* values (Fig. 3).

Aquatic macroinvertebrate densities measured in 1994 were similar to previously recorded values for all streams except Rush Creek (Fig. 4). The 1993 and 1994 macroinvertebrate densities were nearly identical for Rush Creek, but reduced by 50% or more from 1988, 1991, and 1992 values. The two north-facing streams (Rush and Pioneer) both displayed extremely high macroinvertebrate densities (approximately 20,000 individuals/m^2) in 1991, while during the same year the south-facing streams exhibited densities of 1,000-3,000 individuals/m^2. These high densities did not appear to be typical for either Rush or Pioneer, and were likely due to some environmental condition during 1991 that influenced only north-facing streams, possibly related to slower snowmelt. Macroinvertebrate biomass values measured in 1994 were similar to previous years for Rush, Pioneer, Cougar, and Dunce Creeks (Fig. 4). Cave and Cliff Creeks displayed greater biomass values in 1994 than in previous years. Macroinvertebrate biomass in Goat Creek was similar in 1993 and 1994, but reduced by approximately 50% from 1990-1992, a pattern very similar to that of BOM in Goat Creek (see Fig. 2).

Macroinvertebrate taxa richness measured in 1994 was similar in most streams to values obtained in previous years (Fig. 5). In Dunce Creek, taxa richness in 1992 and 1994 was approximately twice as great as in 1990 and 1991. Goat and Dunce Creeks tended to display lower taxa richness values (14-20 taxa) than did the other streams (20-30 taxa). This may have been due to the relatively small size of these two systems and/or the effect of the wildfire. Within any stream, Simpson's Index (a measure of community dominance) displayed a relatively large amount of temporal variation (Fig. 5). In general, Simpson's Index values recorded in 1994 were lower than values obtained in previous years. The exceptions to this pattern were in Cliff and Cougar Creeks, which displayed nearly identical values in 1993 and 1994.

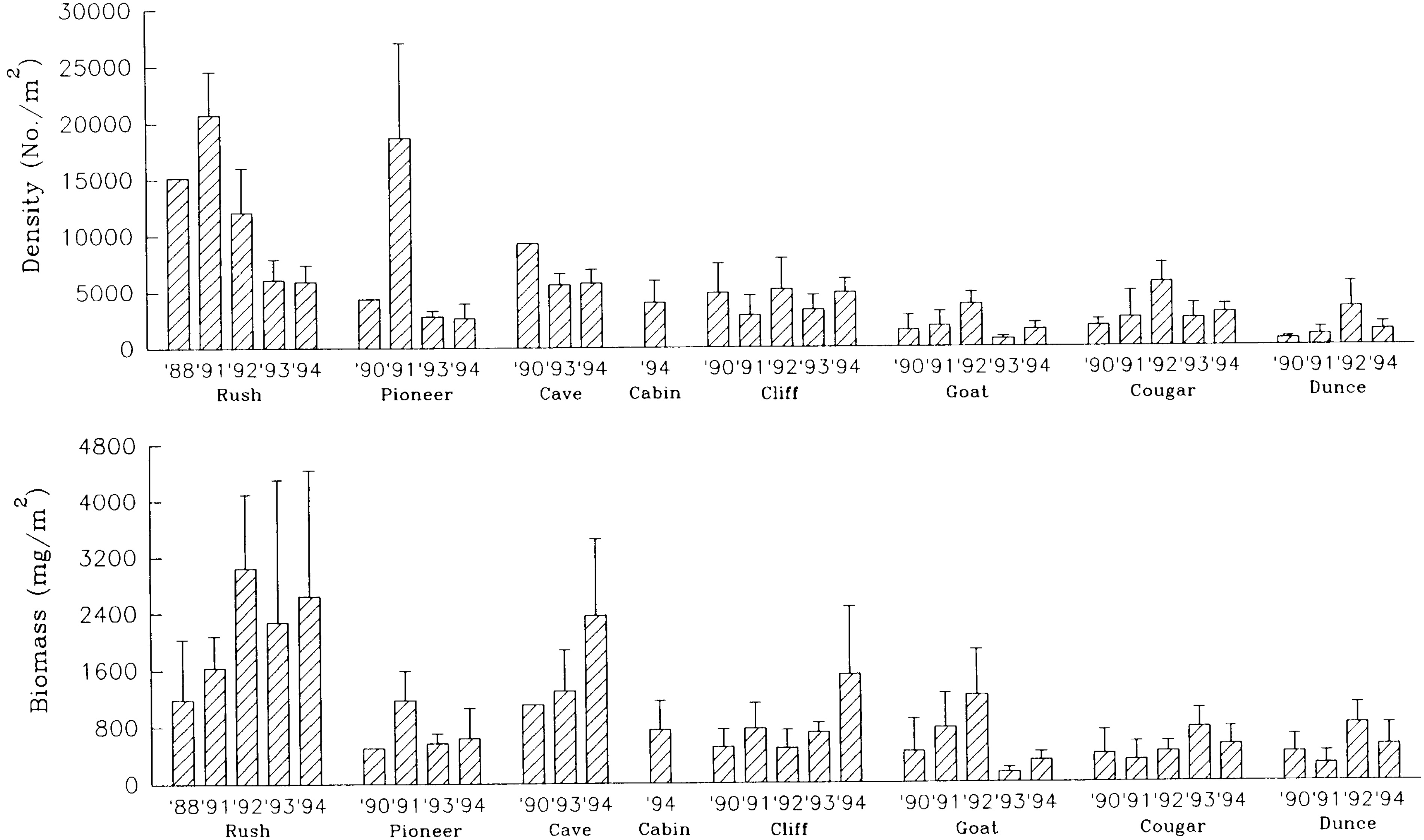

Fig. 4. Macroinvertebrate density and biomass for the study streams. Error bars equal one SD from the mean, n=5.

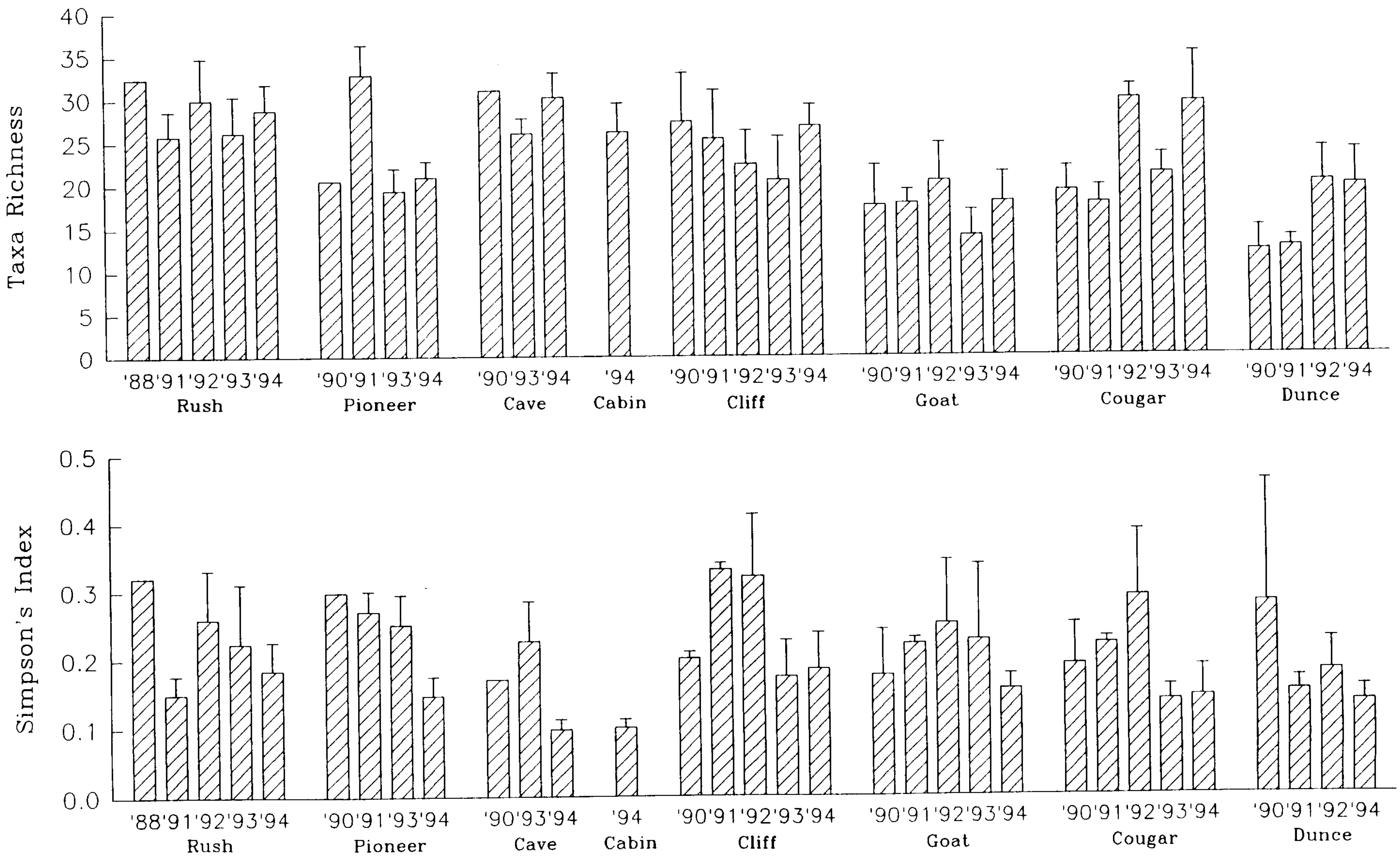

Fig. 5. Macroinvertebrate taxa richness and Simpson's Index for the study streams. Error bars equal one SD from the mean, n=5.

The relative abundances of the 15 most common macroinvertebrate taxa found in 1994 are presented for each stream in Table 5. Chironomidae, Oligochaeta, *Heterlimnius*, and *Baetis bicaudatus* were the most common taxa in all streams except Dunce Creek. In Dunce Creek, *Prosimulium* and *Zapada*, in addition to the above taxa, also were relatively common.

Upper and Lower Cliff Creek Comparison

Benthic habitat conditions were relatively similar in the burned (Upper Cliff) and unburned (Lower Cliff) reaches of Cliff Creek (Table 6). However, specific conductance in the unburned reach was 2x greater than that in the burned reach. Periphyton chl *a*, periphyton AFDM, and BOM were not significantly different between the two reaches. Transported organic matter (TOM; a measure of organic matter suspended in the water column) levels were 2x greater in Upper Cliff than in Lower Cliff. There was no significant difference in substrata size, embeddedness, or stream width between the two reaches. However, the width/depth ratio was significantly greater in the burned reach (Table 6).

The aquatic macroinvertebrate community was notably different between the burned and unburned portions of Cliff Creek. Macroinvertebrate density was 2x greater in burned reach than in the unburned reach ($p<0.05$), although the difference in biomass was slight (Fig. 6). Taxa richness and Simpson's Index also were greater in the burned reach than in the unburned reach, however the difference was significant only for Simpson's Index.

Differences in the functional feeding group (after Merritt and Cummins 1984) composition in the two reaches also were observed. Predators and gatherers represented a significantly greater portion of the macroinvertebrate community in the unburned reach than in the burned reach (Fig. 7). However, miners were significantly more abundant in the burned reach than the unburned. More specifically, the taxa Oligochaeta (a member of the miner functional feeding group) represented 47% of the

Table 5. Relative abundance of the 15 most common macroinvertebrate taxa found in the study streams during July 1994.

Rush Cr.	Rel. Abund. (%) mean	SD	Cougar Cr.	Rel. Abund. (%) mean	SD	Dunce Cr.	Rel. Abund. (%) mean	SD
Chironomidae	33.2	7.2	Baetis bicaudatus	22.8	6.7	Prosimulium	21.8	11.4
Baetis bicaudatus	20.9	5.7	Oligochaeta	20.9	9.5	Zapada	11.9	7.2
Hydracarina	5.9	2.7	Chironomidae	10.6	0.9	Chironomidae	11.6	5.2
Serratella tibialis	5.6	1.8	Heterlimnius	8.8	3.4	Oligochaeta	10.9	5.1
Oligochaeta	5.5	3.0	Cinygmula	5.6	2.1	Baetis bicaudatus	10.1	3.5
Optioservus	4.5	2.1	Zapada	5.3	3.7	Turbellaria	5.2	2.1
Drunella coloradensis	3.6	0.7	Hydracarina	3.6	2.7	Suwallia	3.9	1.1
Epeorus longimanus	3.3	2.8	Epeorus longimanus	2.5	1.4	Heterlimnius	3.1	2.5
Hesperoperla pacifica	2.5	1.2	Turbellaria	1.7	1.0	Parapsyche elsis	2.9	2.6
Simulium	2.1	2.2	Serratella tibialis	1.6	0.7	Narpus	2.7	1.4
Brachycentrus	1.8	1.8	Megarcys	1.3	0.8	Lara	1.9	1.2
Antocha	1.7	0.9	Rhyacophila vagrita	1.2	0.7	Neothremma	1.9	1.3
Atherix variagata	1.0	0.6	Chelifera	1.1	0.9	Paraleptophlebia	1.8	1.7
Heterlimnius	0.9	0.5	Simulium	1.1	0.5	Yoroperla brevis	1.7	1.4
Nematoda	0.9	0.5	Rhyacophila acropedes	1.0	1.1	Nematoda	0.8	1.0
Pioneer Cr.	**mean**	**SD**	**Cliff Cr.**	**mean**	**SD**	**Cabin Cr.**	**mean**	**SD**
Oligochaeta	20.2	10.3	Oligochaeta	26.8	14.6	Chironomidae	17.5	5.6
Baetis bicaudatus	17.1	9.4	Baetis bicaudatus	23.2	10.3	Baetis bicaudatus	13.4	3.4
Chironomidae	16.8	4.8	Chironomidae	6.8	1.5	Hydracarina	9.7	1.9
Epeorus longimanus	8.6	3.3	Drunella doddsi	6.7	1.8	Serratella tibialis	9.2	3.8
Zapada	8.5	3.0	Zapada	5.1	3.1	Heterlimnius	7.9	2.4
Cinygmula	4.9	3.2	Epeorus longimanus	4.8	3.3	Oligochaeta	6.4	3.8
Paraleptophlebia	3.0	3.6	Heterlimnius	4.1	2.4	Micrasema	5.4	4.1
Heterlimnius	3.0	1.2	Cinygmula	3.4	1.6	Paraleptophlebia	4.8	1.4
Calineuria	2.8	0.9	Prosimulium	3.3	3.8	Prosimulium	3.4	3.0
Suwallia	2.6	1.6	Serratella tibialis	2.6	2.2	Zapada	3.0	1.0
Turbellaria	2.4	1.1	Dolophilodes	2.3	2.6	Turbellaria	2.5	1.7
Prosimulium	1.9	0.7	Rhithrogena robusta	1.6	1.4	Ameletus	2.5	2.9
Parapsyche elsis	1.0	0.2	Rhyacophila acropedes	1.1	0.8	Suwallia	2.3	1.1
Rhyacophila acropedes	0.8	0.4	Capnia	1.1	0.6	Rhyacophila acropedes	2.1	0.6
Dicranota	0.7	0.7	Chelifera	1.0	0.7	Doroneuria	1.8	1.2
Goat Cr.	**mean**	**SD**	**Cave Cr.**	**mean**	**SD**			
Baetis bicaudatus	16.6	7.3	Baetis bicaudatus	16.3	2.9			
Oligochaeta	16.4	13.5	Chironomidae	14.5	2.7			
Heterlimnius	13.0	6.0	Heterlimnius	10.8	3.8			
Serratella tibialis	12.6	8.4	Hydracarina	8.5	1.3			
Chironomidae	12.0	6.2	Oligochaeta	7.9	4.8			
Zapada	5.2	4.5	Serratella tibialis	7.8	2.0			
Drunella coloradensis	3.5	0.8	Doroneuria	4.9	2.3			
Yoroperla brevis	2.5	3.8	Prosimulium	4.6	2.8			
Prosimulium	2.1	2.9	Paraleptophlebia	3.4	2.4			
Suwallia	2.0	3.0	Micrasema	3.0	1.6			
Epeorus longimanus	1.9	1.6	Zapada	2.5	2.1			
Nematoda	1.8	1.5	Doliphilodes	1.9	1.7			
Dicronota	1.7	1.8	Brachycentrus	1.6	1.1			
Chelifera	1.3	1.1	Suwallia	1.3	0.8			
Turbellaria	1.3	1.4	Hesperoperla pacifica	1.2	0.8			

Table 6. Benthic habitat variables measured in Upper and Lower Cliff Creek. The p values from t-Tests used to determine habitat differences between the sites also are presented.

	Upper Cliff (burned)		Lower Cliff (unburned)		
Q (m3/s)	0.06		0.09		
Specific Cond. (uS/cm @ 20C)	47		98		
	mean	SD	mean	SD	p Value
BOM (g AFDM/m2)	14.9	12	40.1	28.3	0.118
Periphyton Chl-a (mg/m2)	3.2	0.9	6.3	4.6	0.286
Periphyton AFDM (g/m2)	1.4	0.4	2.1	0.6	0.109
TOM (g AFDM/m3)	8.3	0.8	4.0	0.2	*
Substrata Size (cm)	21	14	19	16	0.501
Substrata Embeddedness (%)	37	25	41	31	0.910
Stream Width (cm)	273	166	201	64	0.581
Width/Depth Ratio	61	25	25	6	0.016

* sample size insufficient for t-Test

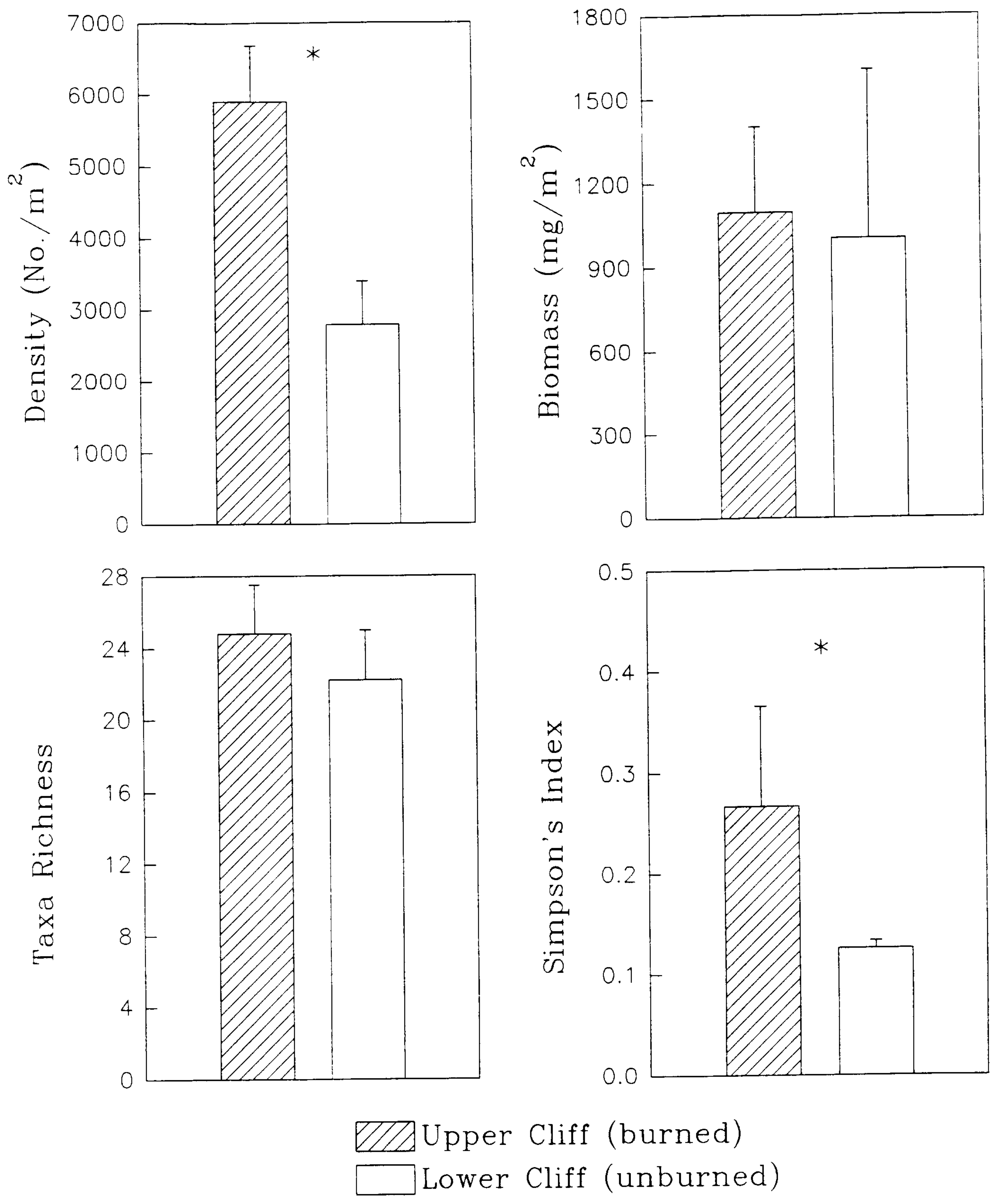

Fig. 6. Density, biomass, taxa richness, and Simpson's Index for the macroinvertebrate communities in Upper and Lower Cliff Cr. during August 1994. Error bars equal one SD from the mean, n=5. * Indicates a significant difference ($p<0.05$, t-Test).

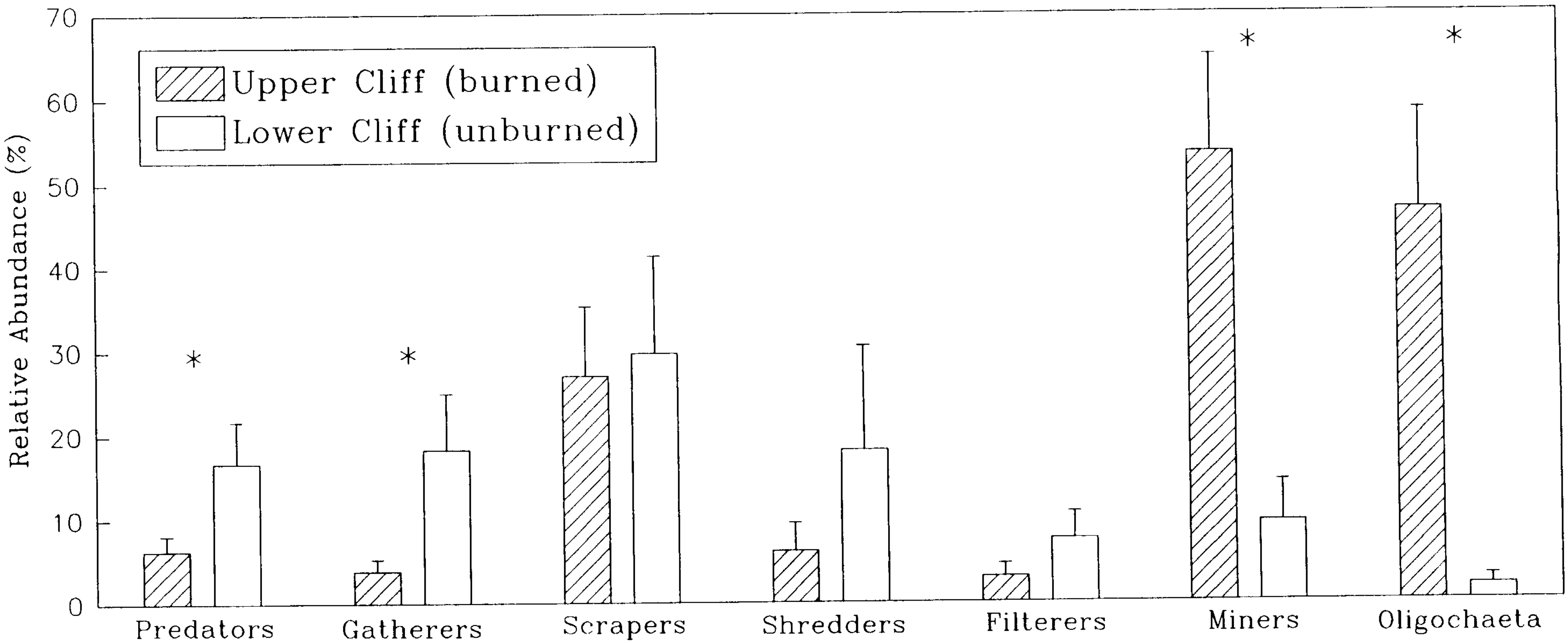

Fig. 7. Relative contribution of the various functional feeding groups to the macroinvertebrate community of Upper and Lower Cliff Cr. during August 1994. The taxanomic group Oligochaeta (a component of the Miner functional feeding group) also is presented. Error bars equal one SD from the mean, n=5. * Indicates a significant difference ($p<0.05$, t−Test).

community in the burned reach, but only 2% of the community in the unburned reach. The relative abundances of the most common macroinvertebrate taxa in each reach are presented in Table 7.

South Fork of the Salmon Tributaries

Fitsum Creek was considerably larger than Circle End, Tailholt, or Pidgeon Creeks and this size difference was reflected in the measures of benthic habitat heterogeneity (Table 8). Substrata size was smallest (7 cm) and substrata embeddedness greatest (76%) in Pidgeon Creek. Pidgeon Creek also displayed a greater stream width/depth ratio (21) than did Circle End (16) or Tailholt (10). In general, visual remnants of previous wildfires (e.g., charred stumps) were more abundant in Pidgeon than the other streams. Specific conductance values recorded in Circle End and Tailholt Creeks were approximately 2x greater than in Pidgeon and Fitsum Creeks.

Levels of BOM were greatest in Pidgeon Creek, although within stream variability was large (Fig. 8). Periphyton chl *a* and AFDM were greatest in Circle End and Fitsum Creeks. In particular, chl *a* values were 6x higher in Circle End and Fitsum, although within stream variation again was large. Circle End and Fitsum also displayed a more open canopy than did Tailholt and Pidgeon.

Diatom species richness was similar among all streams, however Simpson's Index for the diatom communities was considerably greater in Pidgeon Creek than in the other streams (Fig. 9); the diatom community in Pidgeon Creek was dominated by a single species, *Cocconeis placentula* var. *lineata*. The relative abundances of the most common diatom species in each of the streams are presented in Table 9. *Epithemia turgida*, a nitrogen fixing diatom, represented nearly 6% of the diatom community in Fitsum and 2% of the community in Circle End, but was not present in Tailholt or Pidgeon. This suggests that there may be differences in the amount of nitrate present in the

Table 7. Relative abundance of the 15 most common macroinvertebrate taxa in Upper and Lower Cliff Cr.

	Relative Abundance (%)	
Upper Cliff (burned)	**mean**	**SD**
Oligochaeta	46.7	11.8
Baetis bicaudatus	12.7	5.0
Chironomidae	6.9	1.0
Neothremma	5.0	3.4
Yoroperla brevis	3.4	1.3
Glossosoma	3.4	1.1
Arctopsyche	2.6	1.4
Serratella tibialis	2.4	1.9
Zapada	2.2	1.8
Rhyacophila vagrita	1.5	0.7
Turbellaria	1.5	1.2
Cinygmula	1.3	1.2
Drunella coloradensis	1.1	0.7
Rhithrogena robusta	1.0	1.6
Epeorus longimanus	1.0	1.2
Lower Cliff (unburned)	**mean**	**SD**
Zapada	17.0	12.1
Baetis bicaudatus	11.9	4.9
Megarcys	11.3	6.6
Heterlimnius	10.2	6.8
Chironomidae	7.7	6.0
Parapsyche elsis	7.2	3.0
Epeorus longimanus	4.8	4.2
Drunella coloradensis	4.7	5.1
Cinygmula	4.0	3.7
Chelifera	3.2	2.6
Rhyacophila acropedes	2.5	1.8
Rhyacophila vagrita	2.0	1.8
Oligochaeta	1.8	1.1
Rhithrogena robusta	1.4	1.7
Neophylax	1.3	2.1

Table 8. Habitat characteristics measured in the South Fork of the Salmon tributaries.

	Circle End			Tailholt			Pidgeon			Fitsum		
Discharge (m3/s)	0.009			0.017			0.024			0.197		
Conductance (uS/cm)	160			123			75			54		
	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV
Stream Width (cm)	68	17	0.25	116	22	0.19	184	55	0.30	705	108	0.15
Stream Depth (cm)	4	3	0.81	10	5	0.51	12	7	0.62	15	8	0.55
Width/Depth Ratio	16	9	0.54	10	3	0.29	21	9	0.45	26	11	0.43
Substrata Size (cm)	14	39	2.89	13	30	2.35	7	12	1.68	27	27	0.98
Substrata Embeddedness (%)	38	45	1.16	23	33	1.46	76	34	0.45	55	32	0.58

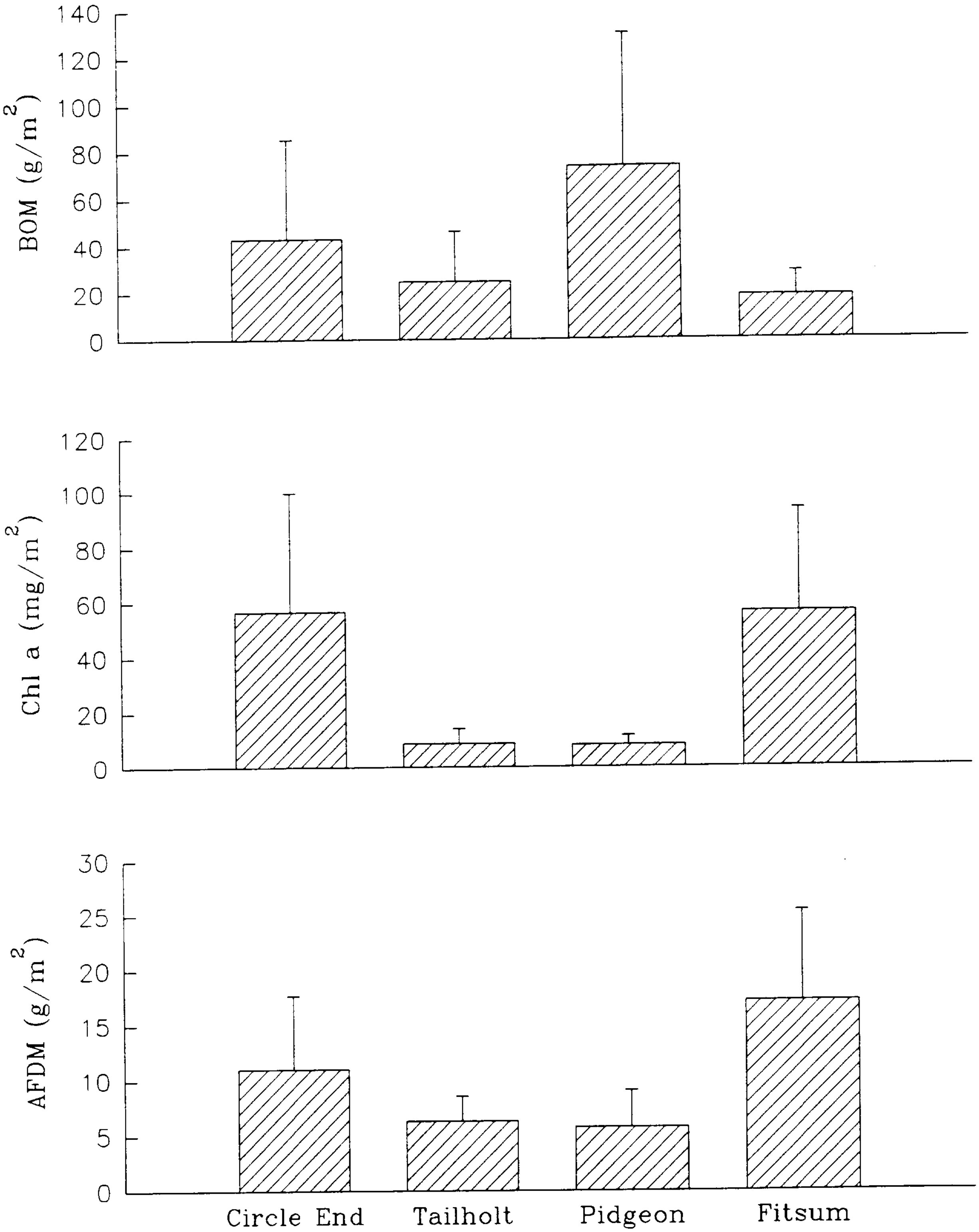

Fig. 8. Benthic organic matter (BOM), periphyton chlorophyll a, and periphyton ash-free dry mass (AFDM) from the South Fork of the Salmon tributaries during Spet. 1994. Error bars equal one SD from the mean, n=5.

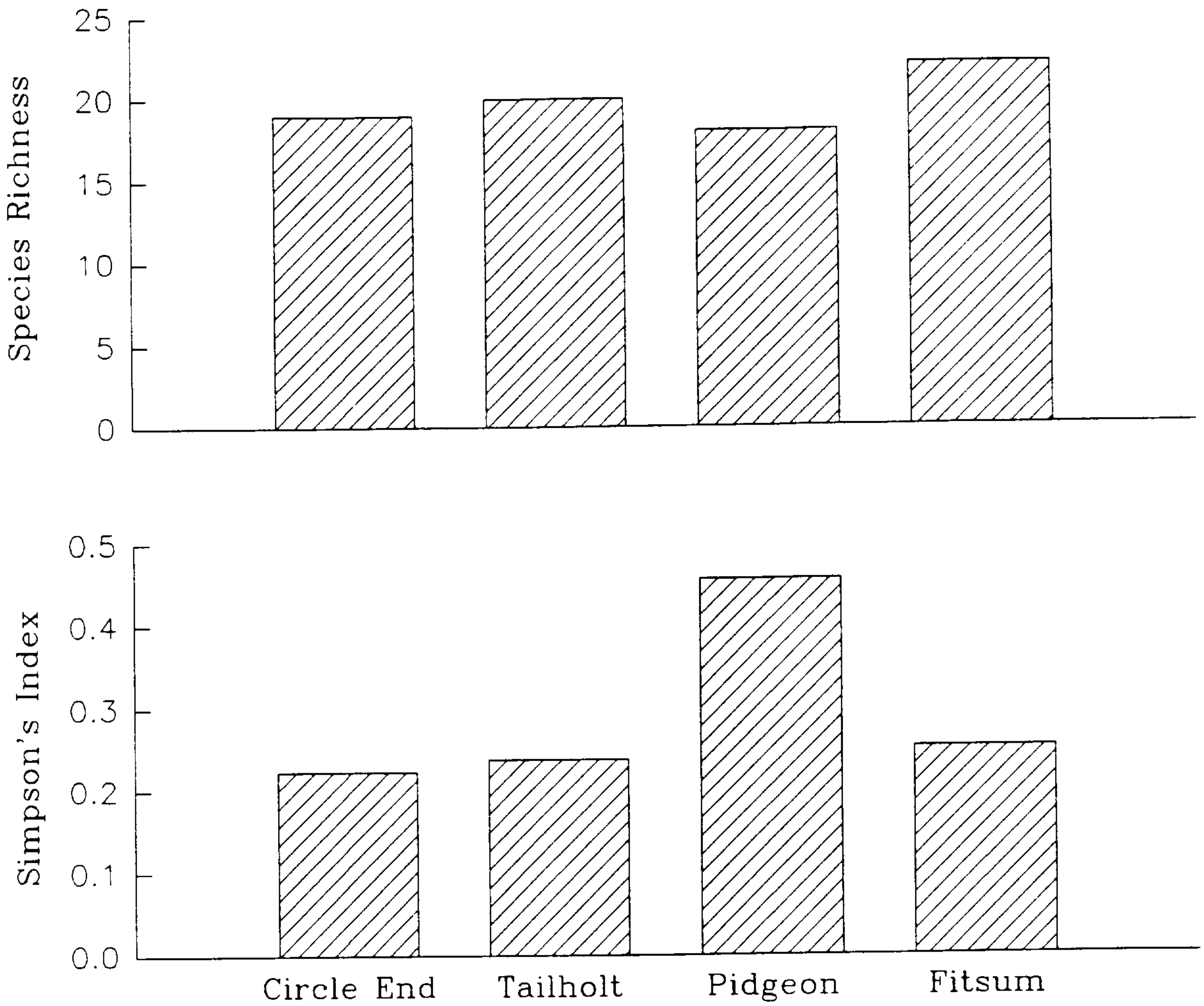

Fig. 9. Species richness and Simpson's Index for the diatom communities in the South Fork of the Salmon tributaries during Sept. 1994.

Table 9. Relative abundance of diatom species representing > 1.0% of the community in each stream.

Stream/Taxa	Rel. Abun. (%)
Circle End	
Rhoicosphenia curvata	33.7
Achnanthes minutissima	22.7
Cocconeis placentula var. lineata	21.0
Fragilaria vaucheriae	10.6
Achnanthes lanceolata	5.0
Epithemia turgida	1.7
Diatoma hiemale var. mesodon	1.2
Tailholt	
Cocconeis placentula var. lineata	39.6
Achnanthes minutissima	19.8
Achnanthes lanceolata	16.6
Cocconeis placentula var. euglypta	10.6
Amphora perpusilla	4.4
Rhoicosphenia curvata	3.2
Nitzschia inconspicua	1.4
Pidgeon	
Cocconeis placentula var. lineata	65.8
Achnanthes lanceolata	9.3
Cocconeis placentula var. euglypta	8.1
Achnanthes minutissima	8.1
Rhoicosphenia curvata	2.9
Fragilaria vaucheriae	1.2
Achnanthes cf. Hungarica	1.0
Fitsum	
Cymbella cistula	36.1
Achnanthes minutissima	33.5
Epithemia turgida	5.7
Cocconeis placentula var. lineata	5.3
Gomphonema parvulum	2.9
Nitzschia paleacea	2.2
Navicula cryptocephala var. veneta	1.8
Nitzschia dissipata	1.7
Synedra ulna	1.7
Achnanthes lanceolata	1.5
Achnanthes lewisiana	1.1

streams.

Aquatic macroinvertebrate density, biomass, and taxa richness were all greatest in Fitsum Creek (Fig. 10). This was likely a result of the larger substrata sizes and greater amount of habitat heterogeneity in Fitsum Creek, relative to the other streams. Macroinvertebrate density, biomass, and taxa richness were similar between Circle End, Tailholt, and Pidgeon Creeks. Simpson's Index was less than 0.22 for all streams, with the lowest value recorded in Fitsum Creek (0.12). The relative abundances of the 15 most common macroinvertebrate taxa in each stream are presented in Table 10. Chironomidae, *Baetis bicaudatus*, *Heterlimnius*, Oligochaeta, and *Yoroperla brevis* tended to be the most abundant taxa in the streams.

DISCUSSION

Big Creek Long-term Monitoring Sites

Distinct changes in the benthic habitat characteristics of Cliff, Cougar, Goat, and Dunce Creeks have not occurred since the wildfires. This is in contrast to results from Yellowstone National Park where major habitat changes occurred following the 1988 wildfires (Minshall et al. 1995, Robinson and Minshall 1993). Increased overland runoff following the wildfires is thought to be responsible for the stream habitat alterations observed in Yellowstone. The dryer climate of the Big Creek catchment, compared to that of Yellowstone, may not have generated sufficient precipitation to create the scouring flows that occurred in Yellowstone. However, Minshall et al. (1989b) examined streams along the Middle Fork of the Salmon River which were influenced by the 1979 Mortar Creek Fire and found major stream channel alterations had occurred during the nine years following the wildfire. Why similar habitat alterations have not occurred in the Big Creek streams is unknown.

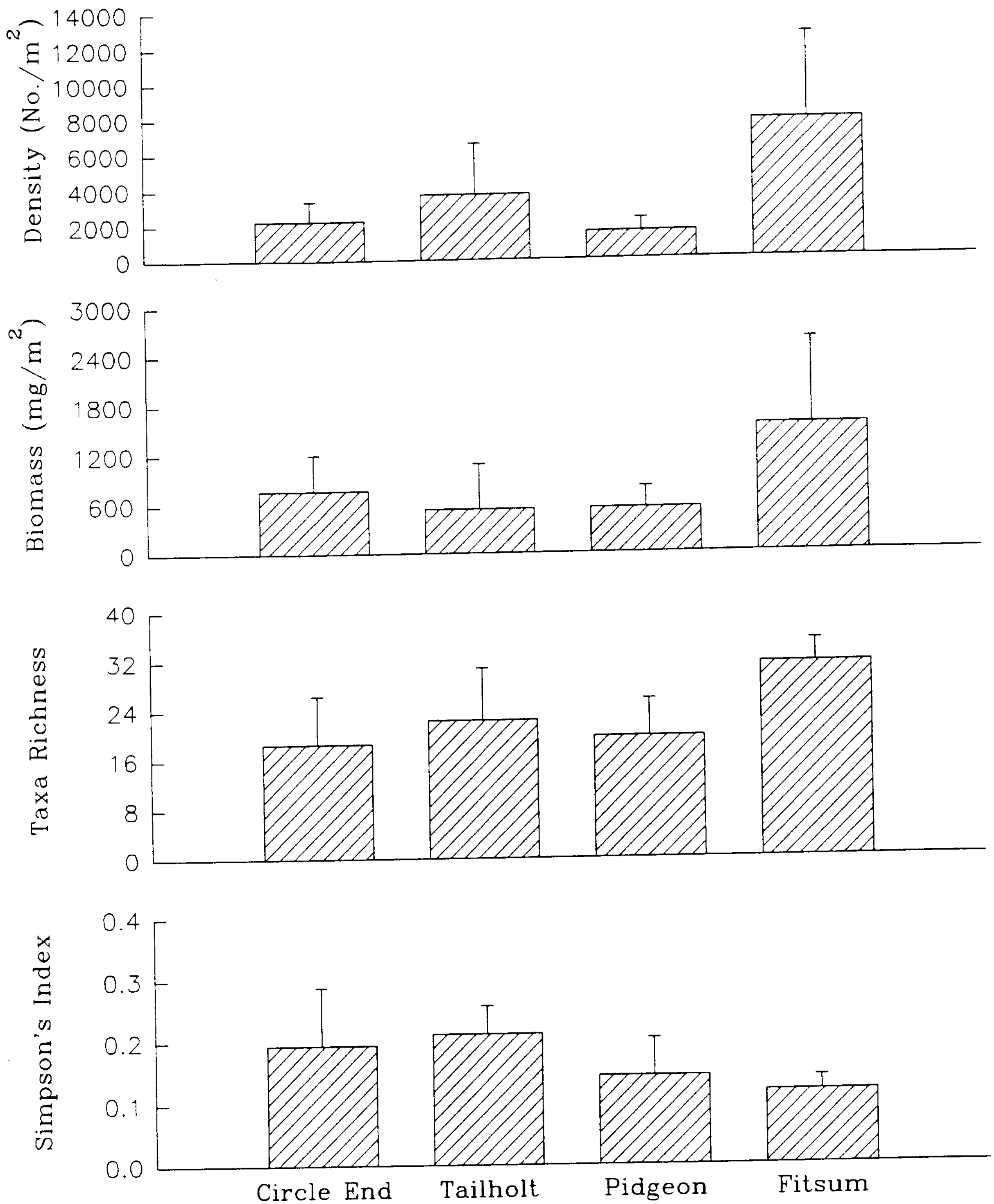

Fig. 10. Density, biomass, taxa richness, and Simpson's Index for the macroinvertebrate communities in the South Fork of the Salmon tributaries during Sept. 1994. Error bars equal one SD from the mean, n=5.

Table 10. Relative abundnace of the 15 most abundant macroinvertebrate taxa in the S.F. Salmon tributaries.

Stream/Taxa	Relative Abundance (%)		Stream/Taxa	Relative Abundance (%)	
Circle End	mean	SD	Pidgeon	mean	SD
Yoroperla brevis	21.5	12.8	Heterlimnius	15.7	5.3
Heterlimnius	16.4	9.0	Yoroperla brevis	14.2	11.9
Oligochaeta	15.8	19.0	Baetis bicaudatus	9.9	7.0
Suwallia	14.3	1.8	Suwallia	9.8	15.4
Paraleptophlebia	3.7	4.3	Oligochaeta	7.0	3.9
Turbellaria	3.5	2.8	Chironomidae	5.8	3.5
Hydracarina	3.3	2.6	Lara	4.0	3.3
Chironomidae	2.9	2.7	Ostracoda	3.9	7.7
Serratella inermis	2.1	1.5	Capnia	3.8	2.9
Dicranota	1.9	1.8	Serratella inermis	3.3	2.3
Braconidae	1.5	3.1	Epeorus deceptivus	2.9	4.6
Baetis bicaudatus	1.5	1.9	Rhyacophila vepulsa	2.8	2.7
Capnia	1.4	1.3	Dicranota	2.6	2.3
Skwala	1.4	2.1	Zapada	2.2	1.5
Zapada	1.2	1.8	Hydracarina	1.7	1.8
Tailholt	mean	SD	Fitsum	mean	SD
Heterlimnius	24.9	12.5	Chironomidae	19.5	7.0
Oligochaeta	23.6	16.3	Baetis bicaudatus	14.6	8.2
Serratella inermis	11.4	12.9	Hydracarina	9.9	5.0
Suwallia	7.2	6.0	Rhithrogena	8.1	6.9
Chironomidae	3.9	3.7	Oligochaeta	7.4	2.0
Yoroperla brevis	3.0	0.9	Cinygmula	5.0	6.1
Baetis bicaudatus	2.4	2.2	Neophylax	3.8	3.5
Turbellaria	2.4	2.5	Paraleptophlebia	3.7	2.5
Isoperla	2.3	2.3	Brachycentrus	3.5	3.2
Dicranota	1.9	3.8	Heterlimnius	2.4	0.9
Hydracarina	1.9	1.1	Arctopsyche grandis	2.1	0.9
Paraleptophlebia	1.8	2.7	Suwallia	2.0	1.1
Capnia	1.8	1.9	Optioservus	2.0	1.4
Rhyacophila angelita	1.3	1.3	Epeorus deceptivus	1.8	1.4
Neothremma	1.3	1.8	Micrasema	1.7	1.2

Water temperature appeared to be influenced most strongly by the amount of riparian shading. Rush Creek (mostly unshaded) consistently displayed warmer water temperatures than the heavily shaded Cliff and Pioneer Creeks. However, Rush Creek also had the largest daily temperature range. Thus, wildfires that remove riparian vegetation and open the stream to direct sunlight should create a warmer and more variable thermal regime within the stream, at least from late spring through autumn; it is unknown how thermal conditions may change during winter. Aspect of the basin may also have influenced the temperature regime of a stream. The amount of alteration in the thermal regime of a stream that occurs following a wildfire may be influenced strongly by basin aspect.

Benthic organic matter was consistently greatest in the streams influenced by the Golden Fire (Goat, Cougar, and Dunce Creeks). A possible explanation for this was that the pre-fire coniferous riparian vegetation was replaced by a deciduous community which then contributed leaf litter to the streams each autumn. Periphyton chl *a* and AFDM appeared to be directly related to the amount of solar radiation reaching stream (i.e., amount of open canopy).

The greatest macroinvertebrate density and biomass were observed in Rush Creek, possibly due to the greater algal resources in that system. It appeared that the Golden Fire may have affected the macroinvertebrate community of Goat and Dunce Creeks; both streams displayed the lowest density, biomass, and taxa richness of all the streams sampled. Dunce Creek has shown a slight increase in taxa richness following 1991, possibly due to recovery from the wildfire. No distinct temporal recovery patterns have yet been observed in the other streams.

Upper and Lower Cliff Creek Comparison

Minshall et al. (1994) noted that Cliff Creek, below the burn perimeter of the Golden Fire, did not display the characteristics typical of a "post-fire stream". However, sampling within the burn perimeter has revealed a strong influence from the Golden Fire on that portion of Cliff Creek within the burn perimeter. Habitat changes in the burned reach (relative to the unburned reach) were similar to changes seen in streams influenced by the Mortar Creek Fire (Minshall et al. 1989b) and in intensely burned catchments of Yellowstone National Park (Minshall et al. 1995). A relatively large width/depth ratio appears to be a common characteristic in streams influenced by wildfire.

The macroinvertebrate community within the burned reach also reflected the influence of wildfire. Macroinvertebrate density was significantly greater in the burned portion of Cliff Creek. However, the increased density was the result of small, sediment-dwelling taxa, primarily Oligochaeta. Indeed, miners (Chironomidae and Oligochaeta) represented over 50% of the macroinvertebrate community in the burned reach. As the riparian community along Upper Cliff returns to a pre-fire condition, sediment inputs to the stream should decline and the benthic habitat become more stable. As this occurs, the macroinvertebrate community should become more evenly distributed among the various functional feeding groups.

South Fork of the Salmon Tributaries

Differences in diatom assemblages were observed between the streams, with Fitsum exhibiting the most distinct diatom community. However, Fitsum Creek is considerably larger (with a more open canopy) than the other streams and it is unknown if the time since last wildfire or more open canopy was responsible for the different diatom community in that system. It is noteworthy that diatom species found to be abundant in streams five years after the Yellowstone wildfires (e.g., *Navicula permitis* and *Nitzschia inconspicua*, see Robinson et al. 1994) were absent or at very low abundances in the S.F. Salmon tributaries. However, the species found in both Yellowstone and the S.F. Salmon tributaries were small, adnate forms.

Fitsum Creek displayed a more dense and taxonomically rich macroinvertebrate community than did the other streams. Whether this difference is due to the larger size of Fitsum Creek or the longer time period since it last experienced wildfire (75 years for Fitsum versus 45 years for the other streams) is unknown. Robinson and Minshall (1991) observed that Doe Creek (a tributary to Big Creek) had recovered from a wildfire that occurred 50 years prior to their sampling effort. Thus, it is possible that Fitsum Creek is no longer influenced by the 1919 wildfire. In general, the hypothesis suggesting concurrent recovery of lotic and terrestrial ecosystems from wildfire is supported by the present study.

The streams influenced by the 1988 Golden Fire and the 1949 Circle End Fire displayed similar macroinvertebrate density, biomass, and taxa richness, despite the difference in the amount of time for recovery. Furthermore, the structure of the macroinvertebrate communities also was similar, with taxa such as *Baetis*, *Heterlimnius*, and Oligochaeta common in both groups of streams. Thus, the seven year burn sites (Goat, Cougar, and Dunce Creeks) and the forty-five year burn sites (Circle End, Tailholt, and Pidgeon Creeks) contained similar macroinvertebrate communities, but were located geologically different areas. This suggests that during the later stages of recovery from a wildfire, factors such as climate and/or geology of the underlying bedrock may become the predominant factors structuring the benthic community.

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